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THE BIOLOGY OF *ANTHOCORIS SAROTHAMNI* DOUGLAS AND SCOTT IN SCOTLAND (HEMIPTERA : ANTHOCORIDAE)

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With 4 Text-figures

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I. Introduction

Anthocoris sarothamni Douglas and Scott breeds exclusively on broom, *Sarothamnus scoparius* (L.), on which it is, however, normally accompanied by *A. nemorum* (L.) and *A. nemoralis* (Fab.). Occasionally *A. confusus* Reut. also is found on broom but it is much less common than the other three species. During the present investigation, population studies revealed that *A. sarothamni* is the most abundant species on broom, clearly outnumbering *A. nemorum*, which, being more catholic in its choice of prey, populates numerous other species of plants (Hill, 1957). *A. nemoralis* forms only a relatively small portion of the *Anthocoris* fauna of broom.

II. Distribution

According to Reuter (1884), *A. sarothamni* is found in Scotland, England, France, Alsace, Belgium. Butler (1923) states that it occurs in the central and southwest parts of the European continent. In England and Wales it has been recorded for

18 of the 52 counties listed by Massee (1955). Its distribution in Scotland is at present being extensively investigated, with that of other Anthocoridae.

III. Materials and Methods

Observations on the life history were made both in the field and in the laboratory. The field studies were carried out during regular and frequent visits to a large plantation of broom growing about a quarter of a mile west of Gartness village, Stirlingshire (Grid Ref. 496866). This plantation covers the south face of a high embankment where the bushes grow in close proximity to one another, with here and there more open areas where brambles, *Rubus* sp., are plentiful. Throughout the year quantitative samples were taken with a beating tray. During most of the period collecting was done by two observers to check the accuracy of the sampling method. The results of these separate samples were highly consistent and the figures reported can be regarded as giving an accurate picture of population fluctuations. As one observer was unable to make a complete set of samples, only the results obtained by the other observer have been used in this account. At each visit collecting was done for a fixed period of time. All specimens were identified, sexed and immediately returned to the bushes. The nymph population was also sampled and, where doubt existed as to identity, specimens were taken to the laboratory and reared to maturity. A search was also made for the presence of ova in the field ; these were readily detected and sampled but, for accurate identification, they had to be examined in the laboratory. The duration of the entire life cycle in the field was calculated by observing the first date on which ova were found and the first date on which pristine adults appeared in the field in midsummer. In 1959 the appearance of pristine specimens among the remainder of the first summer generation, together with the small but distinct second peak in the population graph, gave adequate evidence of the conclusion of the developmental period of the small second generation. The duration of each stadium was obtained from the dates on which individuals of each stadium were first found in the field samples. As regular sampling was done thrice weekly the results obtained must closely approximate to reality. In the laboratory, culture tubes, identical with those already described (Hill, 1957), were used for observations on oviposition. As the nymphs hatched each was transferred to a small gelatine capsule, 25 mm. long by 8 mm. diameter, provided with a strip of filter paper to afford the insect a foothold. Aphids, *Acyrthosiphon pisum* (Harris), were added daily as food in numbers such that the nymph always had more than it could consume in 24 hours. The size of the aphids given was determined by the size of the *A. sarothamni* nymph. In one set of observations the number of aphids consumed per day was recorded throughout the entire developmental period.

IV. Habitat

A. sarothamni is normally regarded as the broom *Anthocoris*, since it occurs exclusively on *S. scoparius* as a breeding species. A search has been made for it on other species of plants, including *Pinus sylvestris* L., *Crataegus monogyna* Jacq., *Betula pubescens* Ehrh., *Quercus robor* L., *Salix* spp. and *Fraxinus excelsior* L., and low growing herbage, but only two specimens were found in September on *Salix* spp. growing in close proximity to broom. Morley (1905) recorded *A. sarothamni* from a dead fir hedge in April where it was thought to have been hibernating. Immature stages have however only been found on broom. It would seem correct to conclude that this species is confined as a breeding species to broom but from it some individuals move as vagrants to other plants, possibly while searching for suitable hibernacula. Whether these succeed in finding acceptable food on such plants is not known. It has however been established experimentally in the present investigation that, in the absence of their normal prey, they will feed on insects not normally found on broom.

V. Field and Laboratory Observations on the Life History

(1) *Hibernation and spring emergence*

The winter is passed in the adult stage. It is somewhat difficult to state precisely when hibernation ceases and the spring activity leading up to oviposition commences because, during the present investigation, active males and females have been collected in every month of the year. From this it may be inferred that *A. sarothamni* is active to some extent at all seasons and, from what is known of the biology of other species, this may well be so. Sunny, mild days in winter are known to cause them to come out of hibernation temporarily. Reference to figure 1, however, will

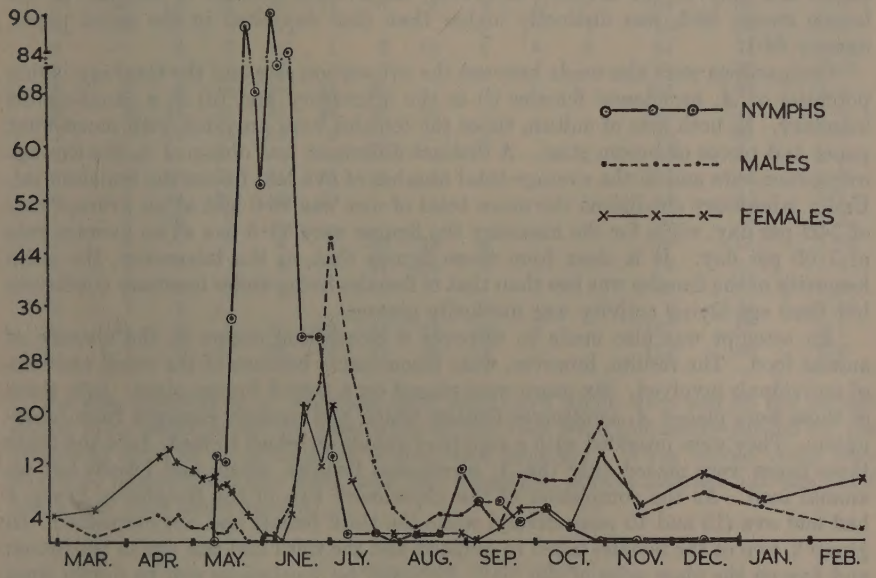

Fig. 1.—Graph of seasonal population fluctuations of *Anthocoris sarothamni* Douglas and Scott.

show that, although a small population of the bug was recoverable throughout the winter, the population progressively and rapidly increased in 1959 after mid-March. Spring, however, came early that year and records for previous years show the spring increase in activity to have begun somewhat later, *e.g.* in the last week of March or even as late as the second week of April in 1958, when winter conditions were much prolonged. The individuals found active throughout the winter thus form only a small proportion of the total overwintering population ; the majority of adults must hibernate in crevices in plant stems, etc. Attempts to locate hibernating bugs in the undergrowth, litter and top three inches of soil beneath broom bushes yielded nothing.

Although males have been found in all samples taken during winter and early spring yet, when the main spring emergence takes place, a markedly disproportionate increase of females over males occurs. This, together with the fact that females dissected during the autumn, winter and early spring invariably have their sperm receptacles full of spermatozoa, shows that impregnation occurs mainly during the previous summer.

(2) *Oviposition*

The oviposition period of *A. sarothamni* is a protracted one, lasting in 1959 from April 15th until June 6th. The ova are inserted in the grooves in the broom stems ;

only rarely were they found inserted into leaflets and then under the artificial conditions of the culture tubes. The ova are never grouped but are placed singly with their long axes parallel to that of the stem. They are not however all orientated in the same direction ; in some the operculum is upwards, in others it is downwards.

A. sarothamni oviposits readily under artificial conditions. In order to investigate whether any preference was shown for oviposition in plant tissue over other materials, *e.g.* moist filter paper, some females were placed singly in 3-inch by 1-inch glass vials provided with moist filter paper together with a short length of broom stem, while others were given only moist filter paper. It was found that a distinct preference was shown for broom rather than paper. All but one of the females which were given the choice laid only on the broom ; moreover, the average number of ova laid in the broom stems, 88·3, was distinctly higher than that deposited in the moist paper, namely 64·1.

Comparisons were also made between the oviposition rate and the total egg-laying potential of *A. sarothamni* females (i) in the laboratory and (ii) in a gauze-walled insectary. In both sets of culture tubes the females were provided with moist filter paper and pieces of broom stem. A distinct difference was obtained in the average oviposition rate and in the average total number of ova laid before the females died. Under laboratory conditions the mean total of ova was 96·0 laid at an average rate of 3·02 per day, while for the insectary the figures were 53·3 ova at an average rate of 1·05 per day. It is clear from these figures that, in the laboratory, the mean longevity of the females was less than that of females living under insectary conditions but their egg-laying activity was markedly greater.

An attempt was also made to discover if oviposition occurs in the absence of animal food. The results, however, were inconclusive because of the small numbers of individuals involved. Six cages were placed on a potted broom plant. Into three of these were placed *A. sarothamni* females which had recently emerged from hibernation. They were provided with a supply of aphids on which to feed. Into the other three cages were placed only the *A. sarothamni* females, which had broom but no animal food. At the completion of the experiment two of the females in group 1 had laid ova (18 and 10 respectively) while the third female had not oviposited. In group 2, two of the females failed to oviposit and the third laid one egg in the broom and five on the glass sides of the vial. Although no conclusions can be drawn from these observations it is perhaps worth noting that, in spite of being deprived of animal food, all the individuals in group 2 survived for 35 days and were, at the end of that period, to all appearances healthy. They were repeatedly observed with their stylets inserted into the plant tissue as if feeding and it is believed that they were in fact obtaining sustenance in some form from the plant. This aspect of the feeding habits of these insects merits further investigation. Additional observations were made later in the season on females which were deprived of animal food after they had been ovipositing for some considerable time. At first all the females continued to oviposit at their normal rate but quite suddenly, after three to seven days, oviposition ceased and all the females were dead by the tenth day. It is suggested that, before starting to lay eggs, the females of *A. sarothamni* may subsist on plant sap for lengthy periods but, after egg laying has been initiated, they require an animal diet to continue their activity and to survive. In nature however it is most unlikely that *A. sarothamni* will ever be deprived entirely of an animal diet, as its main prey, the Psyllid *Arytaina genistae* (Latr.), is never absent. Nevertheless the chances of encountering its prey will be greatly reduced in winter and therefore it may be that *A. sarothamni* supplements its diet with plant juices as described.

A considerable variation occurred in the numbers of ova laid by females even when kept under identical conditions. The minimum was 2 in 13 days. In Table I detailed records are given of oviposition by 17 females collected as they emerged from hibernation in the field. The average longevity of the females observed was 38·4 days.

It will be seen that egg laying, once started, rapidly builds up to a maximum level and then gradually decreases to zero. The maxima for the several females however vary quite considerably (Table I). There was no indication that multiple copulation is necessary for completion of oviposition.

TABLE I.—Anthocoris sarothamni, *spring oviposition records* (*Maxima shown in heavy type*)

Specimen No.	Totals of ova laid in week No.										Total number of ova laid	Length of ♀ life in days	Daily average number of ova
	1	2	3	4	5	6	7	8	9	10			
1	**22**	**15**	**13**	**12**	**11**	**14**	**8**	**8**	**1**	—	104	65	1·6
2	**15**	**3**	.	.	.	.	.	.	.	.	18	10	1·8
3	—	2	2	—	1	2	**10**	6	6	2	31	71	0·43
4	—	—	5	**7**	.	.	.	.	.	.	12	27	0·44
5	6	8	16	29	**32**	20	.	.	.	.	111	37	3·0
6	2	21	19	23	**42**	**42**	10	.	.	.	159	41	3·8
7	3	**13**	**13**	**14**	2	.	.	.	.	.	45	25	1·8
8	**10**	**37**	21	1	.	.	.	.	.	.	69	20	3·4
9	6	15	17	26	**29**	26	5	.	.	.	124	41	3·0
10	6	**23**	22	15	20	.	.	.	.	.	86	30	2·8
11	8	**18**	2	.	.	.	.	.	.	.	28	18	1·5
12	9	—	3	4	7	**19**	**19**	9	.	.	70	65	1·07
13	3	9	3	4	15	**27**	14	1	.	.	76	48	1·6
14	4	6	4	—	—	.	.	.	.	.	14	28	0·5
15	**1**	**1**	—	.	.	.	.	.	.	.	2	14	0·14
16	11	3	7	15	**23**	15	22	18	8	.	122	57	2·1
17	7	2	12	22	14	17	**26**	14	.	.	114	56	2·0

As was observed in *A. nemorum* (Hill, 1957) ova which were laid on the surface of the filter paper or on the glass walls of the vials were frequently sucked by the female in spite of an abundance of food and moisture. When broom twigs were available however the ova were, with one exception, always inserted into the plant tissue and were never sucked.

(3) *Description of the ovum*

The egg of *A. sarothamni* conforms to the general shape of *Anthocoris* ova, being elongate and slightly curved. It is rounded at one end and is provided with a sculptured operculum at the other. In shape the operculum is roughly circular (fig. 2) and shows two distinct zones. A marginal zone consists of a ring of radially elongate " cells ", roughly rectangular in shape but varying somewhat in detail. In width this zone is approximately one-sixth of the diameter of the operculum. The second

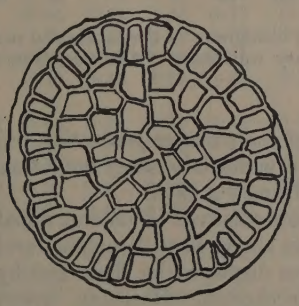

FIG. 2.—Operculum of ovum of *A. sarothamni*.

or inner zone is slightly convex and forms the major portion of the operculum, and is composed of a number of irregular polygonal areas each showing minute sculpturing of a rugose nature. Outside the marginal zone there extends to a varying degree a rim devoid of ornamentation. The operculum is chalky white in appearance and is normally the only portion exposed on the broom plant in nature. The pattern of sculpturing differs distinctly from that of *A. nemorum* (Hill, 1957).

When first laid the ovum is white, opalescent and highly polished. Faintly demarcated polygonal areas corresponding to follicle cells can be discerned on the surface of the chorion.

The ovum averages 0·58 mm. in length (range 0·47–0·63), and 0·24 mm. in width (range 0·22–0·27). In dimensions and in the form of the opercular sculpturing the ova described here differ somewhat from those of the same species described by Sands (1957).

(4) *Incubation period*

Observations were made on the duration of the incubation period in the field, in the insectary and in the laboratory. In the field information was gained indirectly by noting the period between the first appearance of ova and the subsequent first appearance of newly eclosed nymphs. This was found to be 26 days in spring. Field observations were made frequently enough to ensure that the period so obtained must be a very close approximation to the true incubation period under natural conditions at that season.

Under insectary conditions (fig. 3*B*) the ova developed in an average of 14·1 days (range 9–19). Ova laid by the same females but incubated in the laboratory showed an average incubation period of 9·4 days (range 5–17) (fig. 3*A*).

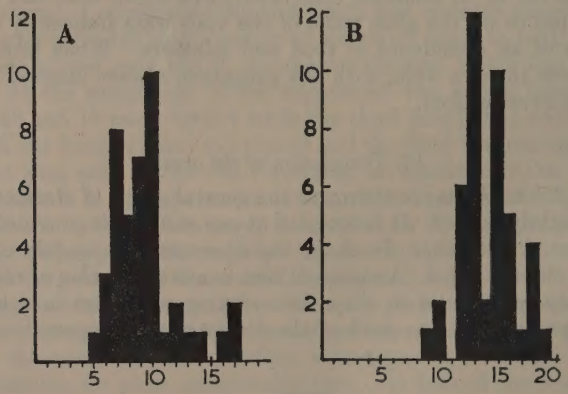

FIG. 3.—Frequency distribution histograms of the incubation period: (*A*) under laboratory conditions; (*B*) under insectary conditions. *Abscissae*, time in days; *ordinates*, number of observations.

A very small minority of the summer generation oviposited and the incubation period required by these ova under laboratory conditions ranged between five days and nine days, the average being 7·2 days.

A small number of ova were observed to undergo a markedly prolonged incubation period. In all cases such eggs appeared to complete development at the normal rate, judged by the colour changes displayed by them and by the form of the contained embryos visible through the chorion. Hatching, however, was delayed for 21–30 days after development was completed under insectary conditions. Only one case

of delayed hatching was noted in the laboratory, eclosion occurring after 25 days. Such examples have been excluded from the ranges of incubation periods given above as they are considered to be atypical. This phenomenon also merits further investigation.

(5) *Eclosion*

The act of hatching from the egg resembles that already described for *A. nemorum* (Hill, 1957) and requires no further discussion here.

(6) *Description of instars, their duration and the amount of food consumed*

First instar

In the field the minimum duration of this first stadium was 4 days, whereas under laboratory conditions the stadium lasted on average 5·5 days (range 3–10), *see* figure 4. There is no significant difference in duration between spring- and summer-reared larvae because of the constancy of conditions in the laboratory. The average number of aphids consumed was 19·75 (4–38). Under insectary conditions the average duration of the first instar was 9·2 days (7–13).

Immediately after eclosion the nymph is a brilliant orange colour but soon becomes darker. *Head :* pale red with eyes deeper red colour, sutures clearly visible; antennae, translucent straw-coloured, except for distal tip of III which is faintly tinged with red, and distal three-quarters of IV which is orange-red. *Thorax :* in general colour more dusky than head; pronotum pale amber, rectangular in shape; mesonotum, pale amber, widening posteriorly; metanotum pale amber, paler than aforementioned. *Legs :* pale amber with femora slightly darker than tibiae and tarsi. *Abdomen :* orange-red with scent glands showing a deeper red through integument of segments 1–3. *Dimensions : see* Table II.

TABLE II.—A. sarothamni, *dimensions of nymphs in millimetres*

Instar No.	Specimen No.	Length of head	Width of head	Lengths of antennal segments					Length of rostrum	Length of pronotum	Width of pronotum	Length of abdomen	Total length
				I	II	III	IV	Total					
1	1	0·27	0·21	0·05	0·07	0·07	0·15	0·34	0·32	0·12	0·25	0·42	0·95
	2	0·27	0·22	0·05	0·07	0·07	0·15	0·34	0·32	0·1	0·25	0·4	0·9
	3	0·25	0·22	0·05	0·08	0·07	0·15	0·35	0·32	0·12	0·25	0·37	0·85
	4	0·25	0·18	0·03	0·07	0·06	0·15	0·31	0·3	0·1	0·22	0·4	0·82
	5	0·27	0·22	0·05	0·07	0·06	0·15	0·33	0·3	0·12	0·22	0·35	0·75
2	1	0·3	0·27	0·07	0·12	0·1	0·17	0·46	0·42	0·2	0·35	0·7	1·25
	2	0·27	0·27	0·07	0·1	0·1	0·17	0·44	0·45	0·2	0·35	0·62	1·17
	3	0·35	0·32	0·07	0·15	0·11	0·2	0·53	0·5	0·2	0·42	0·7	1·25
	4	0·35	0·32	0·07	0·17	0·12	0·2	0·56	0·47	0·2	0·42	0·8	1·5
	5	0·3	0·3	0·07	0·15	0·1	0·17	0·49	0·45	0·17	0·4	0·62	1·4
3	1	0·37	0·32	0·07	0·17	0·12	0·25	0·61	0·5	0·27	0·4	1·0	2·02
	2	0·37	0·37	0·1	0·25	0·17	0·25	0·77	0·57	0·3	0·52	1·2	2·02
	3	0·4	0·32	0·1	0·2	0·15	0·22	0·67	0·55	0·25	0·4	1·0	1·9
	4	0·42	0·35	0·07	0·21	0·12	0·22	0·62	0·62	0·25	0·52	0·95	1·85
	5	0·32	0·32	0·1	0·17	0·12	0·22	0·61	0·5	0·22	0·5	0·92	1·7
4	1	0·45	0·42	0·12	0·35	0·2	0·27	0·94	0·75	0·4	0·82	1·2	2·97
	2	0·5	0·4	0·12	0·27	0·22	0·26	0·87	0·7	0·35	0·6	1·35	2·67
	3	0·45	0·42	0·1	0·27	0·2	0·3	0·87	0·7	0·32	0·62	1·2	2·6
	4	0·42	0·4	0·12	0·27	0·2	0·27	0·86	0·67	0·37	0·57	1·32	2·62
	5	0·47	0·4	0·12	0·27	0·2	0·25	0·84	0·65	0·35	0·57	1·37	2·7
5	1	0·62	0·47	0·12	0·32	0·25	0·32	1·01	0·75	0·45	0·75	1·75	3·55
	2	0·62	0·45	0·12	0·35	0·25	0·3	1·02	0·72	0·4	0·77	1·77	3·4
	3	0·62	0·5	0·15	0·37	0·23	0·32	1·07	0·77	0·45	0·87	1·85	3·55
	4	0·55	0·47	0·15	0·4	0·25	0·32	1·12	0·8	0·45	0·87	2·0	3·62
	5	0·55	0·5	0·15	0·37	0·25	0·32	1·09	0·8	0·45	0·85	2·0	3·67

Second Instar

The minimum duration of this stadium in the field was three days. The average duration in the laboratory was 4·1 days (2–6); 18·15 aphids were killed (9–34); in the insectary the average duration was 6·0 days (3–9) (fig. 4).

Head: amber, eyes red, sutures pale and well marked; antennae, amber suffused with dusky grey except for segment IV, which is wine red; rostrum, dusky grey. *Thorax:* all segments amber coloured suffused with dusky grey. *Legs:* amber with dusky suffusion. *Abdomen:* segments 1 and 2 amber coloured with dusky suffusion as in thorax; remainder wine red with dark internal organs showing through integument posteriorly.

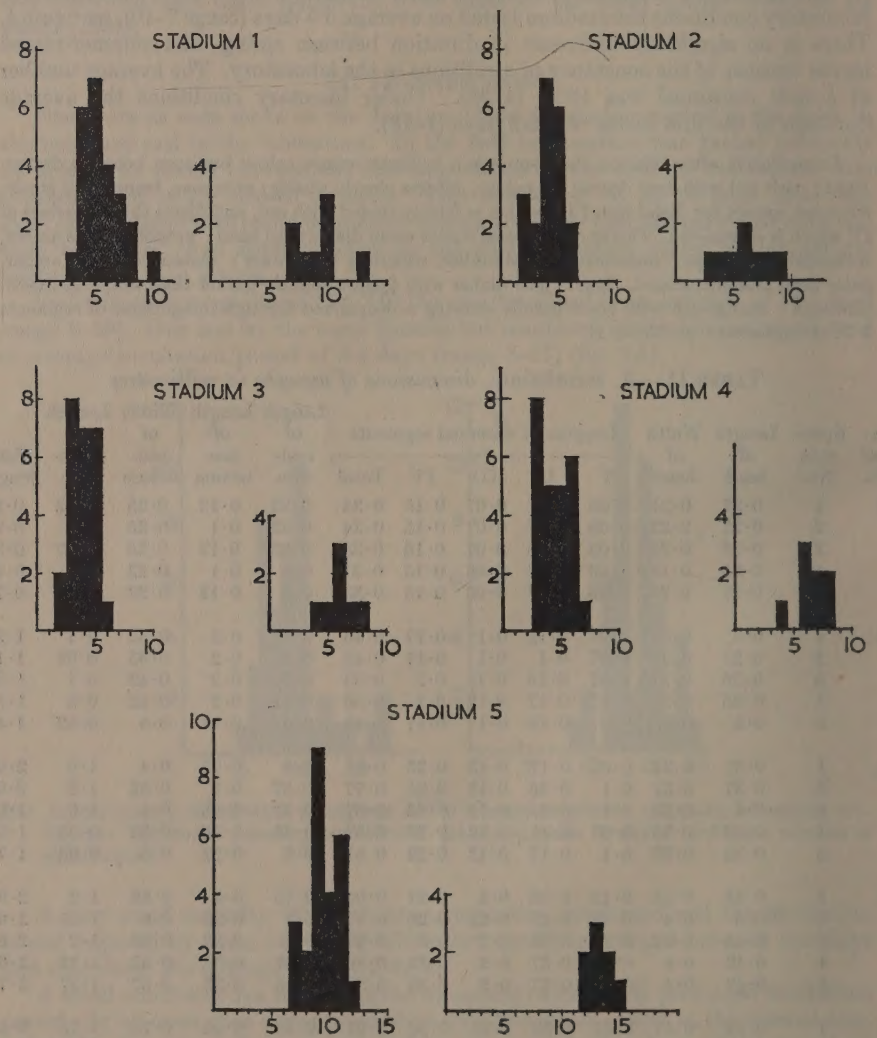

Fig. 4.—Frequency distribution histograms of durations of instars 1 to 5. *Left*, under laboratory conditions; *right*, under insectary conditions. *Abscissae*, time in days; *ordinates*, numbers of observations.

Third Instar

In the field this stadium lasted for four days. In the laboratory its average duration was 3·9 days (2–6). The average number of aphids killed was 19·5 (11–29). In the insectary the average duration was 6·0 days (4–8) (fig. 4).

Head : deep amber with pale sutures ; eyes, wine red ; antennae, segments I–III dusky amber with pale distal zones on segments II and III, segment IV dull red on the distal two-thirds ; rostrum, very dark grey or black. *Thorax :* amber suffused with dusky grey giving a dirty yellow-green hue ; pronotum slightly lighter than other two segments ; wing pads just visible, showing black margins ; posterior margin of metathorax also black. *Legs :* dusky amber, similar in colour to pronotum. *Abdomen :* segments 1–3 dark greenish-brown, remainder deep red, approaching black.

Fourth Instar

A minimum period of 3 days was required in the field for completion of this stadium. In the laboratory it lasted on average for 4·15 days (3–7), and an average of 22·3 aphids were consumed (14–39). In the insectary the average duration was 6·5 days (4–8) (fig. 4).

Head : colour as described for third instar ; antennae, I–III dark grey to black with distal one-eighth of II and one-fifth of III pale cream coloured, IV dark red-brown, slightly paler distally. *Thorax :* colour as in third instar; wing pads further developed. *Legs :* pale testaceous with grey-black suffusion, femora paler distally. *Abdomen :* colour as in third instar.

Fifth Instar

The final stadium had a minimum duration of 11 days in the field, while under laboratory conditions the average duration was 9·4 days (7–12). An average of 39·6 aphids were killed (26–53). In the insectary the average duration was 13·2 days (12–15) (fig. 4).

Head : deep amber coloured ; antennae I–III dark grey to black, with distal extremities narrowly pale creamy white, IV dark red-brown shading to dull red on distal third ; rostrum grey-black, darker at tip. *Thorax :* pronotum deep amber coloured becoming darker laterally ; mesonotum amber coloured mesially, dark red-brown on antero-lateral regions becoming red-brown posteriorly on wing pads ; metanotum, amber tinged with green. *Legs :* amber with dark grey suffusion. *Abdomen :* segments 1 and 2 grey-green in colour, segment 1 being slightly darker than segment 2 ; remainder of abdomen dark brown-red approaching black, pubescence sparse.

(7) *Description of the Imago*

In the field the minimum time required for the complete developmental cycle was 51 days. Records are also available for 36 complete life-cycles studied under artificial conditions (Table III). The average duration in the laboratory was 35·1 days (30–44). During this period 114·4 aphids were consumed on average (87–183). In the insectary an average of 55·1 days (49–65) was required for the complete development.

Head : black, shining with slight pale pubescence ; compound eyes deep red, ocelli somewhat lighter red ; antennae with all segments black, with a distinct pale pubescence. *Thorax :* pronotum black, shiny, with distinct transverse rugosities on short collar and on posterior third behind smooth raised discal callosity ; fine pale pubescence present on pronotum but very sparse on callosity ; posterior margin of pronotum markedly sinuate, lateral margins straight, with anterior angles smoothly rounded behind collar ; scutellum black, divided by transverse sulcus into an anterior raised and rounded portion and a posterior portion with flatter contours and shallow irregular transverse striations ; a distinct fine pubescence resembling that of pronotum present. *Elytra* entirely covered by moderately dense but short pubescence ; clavus entirely dull,

TABLE III.—*Showing in column (a) duration of various stadia and in column (b) the numbers of aphids consumed per stadium by developing nymphs of* A. sarothamni

Specimen number	Incubation period in days	Stadium number 1 (a)	1 (b)	2 (a)	2 (b)	3 (a)	3 (b)	4 (a)	4 (b)	5 (a)	5 (b)	Totals: Developmental period	Totals: Aphids consumed
1	6	4	4	5	11	4	15	5	25	7	32	31	87
2	7	8	14	5	17	4	19	3	14	7	43	34	107
3	7	6	15	4	18	3	18	3	22	11	46	34	119
4	7	7	21	4	16	3	19	3	19	11	35	35	110
5	7	6	19	5	31	3	17	3	18	8	47	32	132
6	6	4	11	5	18	3	17	3	17	9	47	30	110
7	6	4	21	6	2	4	25	4	25	9	44	33	117
8	7	3	8	4	17	2	14	4	23	12	43	32	105
9	5	6	23	2	10	3	12	6	23	9	51	31	119
10	8	10	36	6	34	4	22	6	38	10	53	44	183
11	8	5	10	4	14	5	28	3	19	9	46	34	117
12	8	6	15	3	13	3	19	6	39	10	41	36	127
13	10	4	21	5	23	5	21	7	34	11	33	42	132
14	8	6	19	4	26	5	26	4	23	9	45	36	139
15	7	7	26	3	17	5	27	4	25	9	45	35	140
16	8	7	32	5	24	5	29	5	20	10	45	40	150
17	8	6	21	5	27	5	28	5	30	10	46	39	152
18	7	9	38	5	21	4	17	4	16	12	43	41	135
19	7	8	37	5	20	4	18	5	22	12	35	41	132
20	6	6	22	3	18	3	12	4	19	9	37	31	108
21	7	6	26	3	16	4	16	5	23	11	43	36	124
22	8	5	21	4	19	3	11	5	17	10	35	35	103
23	7	5	24	3	16	3	14	5	25	10	38	33	117
24	5	5	24	3	9	4	17	4	16	10	35	31	101
25	6	5	19	3	12	4	11	5	15	10	35	33	92
26	7	6	16	5	19	7	21	4	14	8	26	37	96
27	8	6	17	4	19	5	11	5	23	7	26	35	96
28	7	6	19	6	23	5	15	4	23	7	27	35	107
29	7	7	24	4	13	5	16	4	19	7	26	34	98
30	7	5	15	4	17	4	12	4	16	7	28	31	88
31	10	7	.	3	.	5	.	3	.	10	.	38	.
32	10	5	.	2	.	5	.	4	.	9	.	35	.
33	9	4	.	4	.	4	.	3	.	9	.	33	.
34	9	5	.	2	.	5	.	5	.	9	.	35	.
35	9	5	.	5	.	2	.	4	.	9	.	34	.
36	7	5	.	4	.	4	.	4	.	8	.	32	.

dark brown to black; narrow dull strip also present along margin of corium, which adjoins the clavus; corium otherwise shiny and dark brown or almost black except at proximal end where it is dark amber coloured; embolium shiny, testaceous, becoming dark brown distally; cuneus very dark brown or black, shiny; narrow but distinct glabrous margin along border between membrane and cuneus and corium; membrane dusky brown with one lateral pale area per side and an antero-median less distinct, pale area. *Legs:* femora very dark brown or black, tibiae pitchy, tarsi dark brown or black. *Dimensions* of adult males and females as in Table IV.

(8) *Colour variations in the adult*

To the unaided eye *A. sarothamni* usually appears to be a small, shiny black insect. However, closer examination reveals that in many individuals there is a degree of russet brown coloration on the hemelytra. This is particularly noticeable on the clavus which may show a range of colour differences from a small indistinct russet coloured shadow on its proximal half to a clearly marked russet area occupying the whole of the clavus except its extreme distal angle. When the latter is the case the russet colour also extends to the proximal half of the corium and is clearly visible to the unaided eye. These colour differences do not appear to be related in any way to sex or to the age of the individual or to show any correlation with the seasons. In preserved material the russet colour tends to fade somewhat. In some specimens the second antennal segment is black on proximal fifth and distal two-fifths, the rest being piceous.

TABLE IV.—A. sarothamni, *dimensions of adults in millimetres*

Sex	Specimen No.	Length of head	Width of head	Lengths of antennal segments I	II	III	IV	Total	Length of rostrum	Length of pronotum	Width of pronotum	Length of scutellum	Length of elytra	Total length
♂	1	0·47	0·47	0·17	0·42	0·27	0·32	1·18	0·92	0·57	1·1	0·52	2·0	3·56
	2	0·45	0·47	0·17	0·47	0·27	0·32	1·23	0·75	0·55	1·1	0·55	2·0	3·55
	3	0·42	0·5	0·15	0·45	0·27	0·35	1·22	0·85	0·55	1·1	0·55	2·02	3·54
	4	0·45	0·5	0·16	0·47	0·27	0·3	1·2	0·8	0·55	1·07	0·55	2·05	3·6
	5	0·5	0·47	0·15	0·45	0·27	0·32	1·18	0·7	0·52	1·1	0·5	2·02	3·54
♀	1	0·42	0·47	0·15	0·47	0·27	0·32	1·21	0·85	0·55	1·17	0·62	2·25	3·84
	2	0·45	0·5	0·2	0·45	0·25	0·32	1·22	0·87	0·52	1·2	0·55	2·17	3·69
	3	0·5	0·5	0·17	0·47	0·27	0·35	1·26	0·87	0·52	1·17	0·55	2·22	3·79
	4	0·5	0·5	0·15	0·47	0·27	0·32	1·21	0·97	0·5	1·2	0·52	2·07	3·59
	5	0·47	0·47	0·15	0·45	0·25	0·32	1·17	0·85	0·55	1·17	0·52	2·12	3·66

VI. FOOD AND FEEDING BEHAVIOUR

A. sarothamni appears to be restricted in its natural diet to species of prey which are present on broom. Collections of the general insect fauna of this plant have been made at regular intervals throughout the year so that every possible prey species might be examined. Direct observations have also been made on the feeding activities of the bug in the field and in the laboratory and these have shown that the main prey is limited to three species of insects, *Arytaina genistae* (Latr.), *Trioza urticae* (L.) and *Acyrthosiphon pisum*.

Undoubtedly the most important species is *Arytaina genistae*, which is present in varying numbers in every month of the year ; it has even been found in copulation in the field in December. The psyllid nymphs first appear after mid-April and rapidly increase in numbers until they are extremely abundant and form the major members of the broom insect fauna. The over-wintered adults begin to disappear by early May and progressively decline in numbers until the last week of that month. The first of the summer adults appear immediately thereafter during the first week of June, and again are present in vast numbers.

Meanwhile the aphid species *Acyrthosiphon pisum* has played a very minor role in the broom fauna complex and it is believed that during spring and the first half of summer it is of little importance as food for *Anthocoris sarothamni*. Nymphal fundatrices are not easily detected. The first fundatrices to reach maturity do so about the end of April, by which time the psyllid adults are still present in fairly large numbers and the psyllid nymphs are increasing rapidly. Even by the first week in June, when adult psyllids are at their peak of abundance, aphids are still relatively scarce. By the third week of June psyllid numbers decrease noticeably until by early July adults are only fairly common, while the nymphs are very few. By the end of July nymphs are almost absent and the number of adults has also decreased further. However, adults and nymphs of *Acyrthosiphon pisum* are now plentiful.

Throughout August the adult psyllid population remains low and only a few nymphs are present. Field observations on the feeding habits of *Anthocoris sarothamni* showed that, as psyllids decrease in abundance and *Acyrthosiphon pisum* increases, nymphs of the latter form an increasingly higher proportion of the bug's food. A second peak in the numbers of psyllids appears during the last week of September but this is much smaller than the summer rise in numbers. This early autumn increase in psyllid numbers is caused by the influx of individuals of *T. urticae* from nettles. Broom is one of the plants on which this species normally overwinters. From then on psyllid numbers decline but never reach zero, for both species of psyllids can be collected from broom throughout the winter. *A. pisum* likewise declines in numbers at the end of summer and ultimately disappears during the autumn, or early winter.

As has been stated above, it is known that *Anthocoris sarothamni* does suck plant juices, but to what extent this occurs in nature, and how important it is for the survival of the insect, is as yet not known.

VII. Copulation

When males and females were placed together in culture tubes, copulation or attempted copulation commenced within a few seconds. If the female had already mated she displayed restlessness to a degree which caused the male to separate from her. If the pair subsequently encountered each other the male invariably attempted to copulate again with the same result.

Virgin females, on the other hand, readily accepted the males. The male mounted the female and lay dorso-laterally and to her right side. He grasped her with his three left legs which were placed (1) on her pronotum, (2) at the insertion of the left hemelytron and (3) at the cuneus of the left hemelytron. Right leg 1 was lifted up while right legs 2 and 3 reached the substratum and supported the male's weight.

During copulation the male's antennae were held laterally and backwards in a plane slightly above the horizontal. Those of the female were held in a similar plane but pointing forwards. For the most part the antennae remained motionless. The female's body was inclined steeply downwards to the left; her head was depressed and the tip of her abdomen was raised well above the substratum. The left ventro-lateral surface of the male's body was in contact with the right ventro-lateral surface of the female's body, allowing the insertion of the left paramere of the male to be accomplished.

In one observation, after a period of 28 minutes the female became restive and started to walk carrying the male with her. In a short time she crawled into a crevice, and this had the effect of causing the male to release his hold and separate from her. Thereafter the female "cleaned" her antennae with her front tarsi. On emerging from the crevice half a minute later, she was again attended by the male, which mounted but did not succeed in bringing its abdomen in contact with that of the female before he was again displaced by her activity. This was repeated a number of times until ultimately their abdomens did make contact. Then the female became quiescent and remained so for a further eight minutes behaving as already described. At the end of that period the female again displayed restlessness, moving with great rapidity at times, without succeeding in displacing the male. During these movements her antennae were held antero-laterally and raised and lowered rather slowly. These movements by the female continued for a period of 8·5 minutes before the male was finally displaced. Observations were continued for a further 30 minutes but the male did not attempt to mate again.

VIII. Number of Generations per Annum

Butler (1923) stated that "the insects of the year mature early in August or perhaps late in July". That two generations can occur per annum was indicated by Sands (1957) who contrasts the oviposition behaviour of the summer generation with that of the spring generation. The autumn generation is said to occur from late August onwards and constitutes the spring generation in the following year.

The actual dates of appearance of the various developmental stages are dependent upon climatic factors and during the present investigation considerable variations have been observed, *e.g.* between 1958, in which the weather conditions were rather poor, and 1959, in which the weather was exceptionally good.

In 1958 the spring was slow in coming and early collecting in February and March yielded no adults of *A. sarothamni*. It was not until April 10th that the first specimens appeared. A warm period during the following week brought about the sudden appearance of numerous adults. Thereafter the weather again deteriorated, and no ova

hatched in the field until June 14th. Meanwhile the overwintered adults, which had been ovipositing, were progressively decreasing in numbers until by May 28th all had died. The earliest adults of the summer generation appeared about the third week in July and were to be found thereafter until the end of August, by which time the majority had disappeared. Throughout the winter months, however, a very few adults could always be collected by beating broom bushes (*see above*).

In 1959 the spring came early and the first signs of increased activity amongst adult *A. sarothamni* was recorded on February 27th (fig. 1). This no doubt happened in response to a period of mild weather which occurred at that time. After March 17th the numbers of adults increased rapidly to a maximum on April 20th. On that date also the first ova were found in the field. The exceptionally fine and warm weather was undoubtedly responsible for the markedly early appearance of nymphs on May 11th, *i.e.* rather more than one month in advance of the previous year's records. Thereafter the nymph population increased rapidly, reaching its maximum during the first fortnight in June. In 1959 there was no prolonged hiatus when overwintered adults had disappeared and summer adults had not yet developed, indeed there was a slight overlap of generations. The first adults of the summer generation appeared on June 8th, *i.e.* more than six weeks before the date of their appearance in 1958. The population of nymphs thereafter declined rapidly until all had disappeared by July 26th. A marked preponderence of males over females was noticeable in the summer generation.

The first indication that a second generation could occur in the field was obtained on August 7th, 1959 when a single first instar nymph of *A. sarothamni* was collected. Subsequently the numbers of nymphs increased but never attained a high figure—a fact which lends support to the conclusion, formed previously from laboratory studies, that only a small proportion of the summer generation oviposit, given suitable conditions, while the majority do not, even although they are subject to the same environmental factors.

The first individuals of the second generation to become adult did so on September 14th and a distinct though small peak is clearly to be seen in the population figures obtained thereafter (fig. 1). All the second generation nymphs had completed their development in the field by the last week of October. That they were able to continue to develop to this late date was undoubtedly due to the exceptionally prolonged warm conditions which prevailed well into the autumn.

All the nymphs collected in the field in late summer were reared to maturity in the laboratory and all were confirmed to be *A. sarothamni*. It is interesting to note that, even under the exceptionally favourable conditions of 1959, no second generation of *A. nemorum* occurred, *see* Hill (1957).

Dissections were made of females of *A. sarothamni* which had been caught in the field and which had shown no signs of ovipositing after a considerable time in the favourable conditions of the laboratory, and of similar females which had been reared entirely in the laboratory. In all cases it was found that they were not, physiologically, ready to reproduce. Although their sperm receptacles were full, their ovaries were small. The exact nature of these reproductive dissimilarities is a subject for further investigation. It may be significant that two of the three laboratory-reared females which gave second generation nymphs were of the same parentage.

Although the great majority of females which had reached maturity during the summer both in the field and in the laboratory did not oviposit, it was none the less found possible to obtain ova from females of this generation considerably later in the year. Thus, ova were laid by females collected in the field on November 3rd. A period of 18 days elapsed before oviposition commenced. Similarly, summer generation females, which had been reared in the laboratory and had failed to oviposit before the end of summer, were found capable of ovipositing after a period of 55 days in a 4° C. constant temperature cold room. Transference to the warmer laboratory

took place on November 25th and ova were laid 16 days later. Control individuals, which had been kept all their lives in the laboratory and had remained active and feeding well into autumn, all died without laying ova; moreover, their deaths occurred before the other specimens were removed from the cold room.

It would appear, therefore, that under normal summer conditions in these latitudes *A. sarothamni* is univoltine. However, a small portion of the population appears to display facultative bivoltinism and can produce a second generation in the laboratory and, during exceptionally fine summers, in the field also.

The majority of first generation females after copulation quickly leave the broom and appear to enter hibernation early. Under normal field conditions of autumn and winter such individuals remain dormant for most of the time. A few become temporarily active during mild days but never oviposit until the following spring. Whether or not subjection to low temperatures is essential for gonadial development is uncertain; nor is it clear yet whether a true reproductive diapause is involved.

IX. Summary

The distribution and habitat of *A. sarothamni* are described. Observations in the laboratory and field under Scottish conditions have shown that emergence in the spring occurs between mid-March and the second week in April, depending upon climatic factors. Descriptions are given of all stages in the development of the insects and mention is made of colour variations in the adult insects. Observations are recorded on oviposition, the situations in which the eggs are laid, and the duration of the various stadia, in the field, the laboratory and the insectary, and details are given of the amount of food consumed and on behaviour during feeding and copulation. It was found that the main prey consisted of *Arytaina genistae* and *Acyrthosiphon pisum*. It was found that, under laboratory conditions and in exceptionally favourable climatic conditions in the field, some of the first generation females oviposited and so gave rise to a small second generation which reached maturity in late summer. It would appear that under less favourable conditions in the field no second generation occurs in Scotland. Details are given of seasonal changes throughout the year in field populations of *A. sarothamni*, which, persisting at a low level throughout the winter, increase in the spring.

X. Acknowledgments

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